(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 February 2001 (08.02.2001)

PCT

(10) International Publication Number
WO 01/09724 A1

(51) International Patent Classification[7]: G06F 11/25, 11/273, G01R 31/319

(21) International Application Number: PCT/US00/19662

(22) International Filing Date: 20 July 2000 (20.07.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/362,108 28 July 1999 (28.07.1999) US

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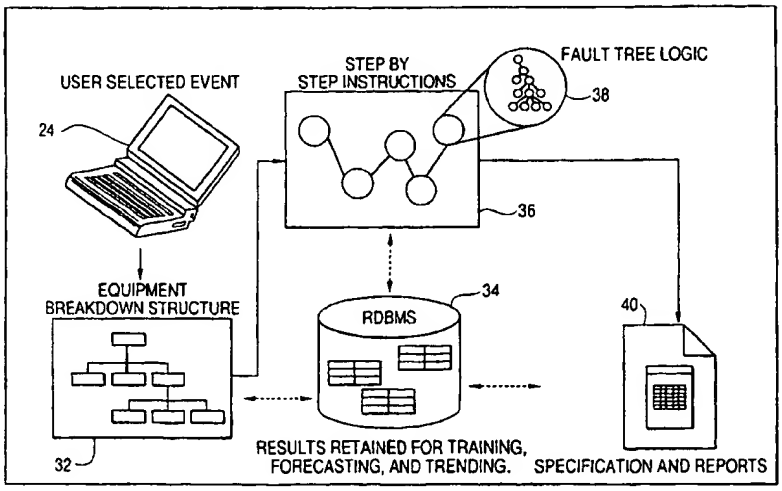
(81) Designated States *(national)*: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: MOBILE MAINTENANCE ASSISTANT




(57) Abstract: A maintenance assistance system which guides an inspector through an inspection process on a component of a system. A main processing system stores and serves a component breakdown structure for the system allowing the identification of the component. The main processing system also serves an inspection wizard, typically in the form of an expert system, that accesses a data structure for guiding the inspector through the inspection process. The inspector accesses the component breakdown structure and the maintenance wizard using a remote processing system, such as a personal data assistant or handheld class computer to allow an on-site inspection. The maintenance system records the observations of the inspector and produces a work specification describing needed maintenance for the component.

WO 01/09724 A1

## TITLE OF THE INVENTION

MOBIL MAINTENANCE ASSISTANT

## BACKGROUND OF THE INVENTION

The present invention is directed toward a computerized system for guiding relatively inexperienced workers through a complex inspection processes on components of large, expensive and complex systems such as naval ships or large industrial facilities.

Massive machines of the present age are typically complex systems constructed of equally complex components, sub-assemblies and/or parts. For example, a modern day naval vessel is constructed with thousands of components, each in turn comprising their own sub-components and/or parts. For the purpose of describing the present invention the term system is used to generically refer to an entire machine or construct, while the term component is used to refer to the individual sub-systems, assemblies or pieces of equipment that make up the entire machine or construct. Thus, a system has at least one component, which, in turn, may comprise at least one component, and so-on.

The massive machines of the present age, for example an aircraft carrier, require intensive maintenance routines by a highly skilled work force. Unfortunately, much of the required skill can only be gained by years of hands on experience. Consider the case of a United States Navy ship. First, the U.S. Navy currently accepts two to four year enlistment periods. Given the complex system present by a U.S. Navy ship, just as personnel become competent at maintaining the aircraft carrier, their enlistment periods are up. Secondly, there is, currently, a recognized shortage of experienced/trained technical personal which severely limits the number of experienced maintenance personal. As only a limited number of experienced technicians are available at any one time, much of the routine inspections and initial troubleshooting attempts must be performed by relatively inexperienced persons. This problem is experienced by each of the branches of the armed forces and in many civilian endeavors, such as in the utilities or other complex industrial facilities.

Unfortunately, as in the defense industry, the gap of "needed" vs. "available" highly technical, trained maintenance engineers has reached a critical level. This is a result of two significant factors. First, technology and equipment are evolving at such a rapid pace that the technicians can no longer develop the expert knowledge that was historically gained by maintaining a piece of equipment for years and even decades. Second, lost expertise in the

maintenance of mission critical equipment is a result of the aging workforce, downsizing, and contracting out non-core business functions. A combination of downsizing work force and contracting out non-core business functions has left corporations vulnerable.

The retirement of a significant number of expert maintenance engineers is a phenomenon experienced in all areas of industry. These individuals have developed skills and possess tacit knowledge of specific equipment. Younger, less technical individuals are assuming their responsibilities and would benefit from access to a repository of years of experience.

In short, in public and private industry, due to international marketing, global location of facilities, the mobile workforce, and worldwide responsibilities, it is simply not possible to have the necessary technical expertise when needed. On naval vessels, as in many other industries, inspections are performed by junior level personnel using printed checklists and associated observation forms. Each component in the system will have a related check list and observation form, many times the checklist and form are combined into a single document. For example, a pump would have a check list of the various parts to check, such as seal, shaft, electrical contacts, etc.. The check lists may or may not be specific to a particular pump. Personnel are trained to follow the check list and write down various observations, such as a leak rate of a seal or condition of electrical contacts on the pump. These observations would then be reviewed by a more senior technician who writes a work order (or work specification) to fix any perceived problems. These work orders are in turn sent to the appropriate repair facility, on-board or ashore, for assignment of resources, including personal, time and parts, for completion of the repair.

Not unsurprising, the junior personal responsible for the initial inspection make mistakes and, as a group, produce reports of a widely varying accuracy and relevancy. This may be simply a matter of experience, but the problem is increased by a lack of language skills in our diverse work force. One of the more common mistakes is the misidentification of the component being inspected, either through language problems or simple inexperience. A related problem is that an experienced technician would be able to recognize that certain observed facts indicate a certain failure mode, possibly affecting other components not under inspection, that requires further inspection of items or conditions not on the checklist.

Unfortunately, the experienced technicians who have the experience to produce accurate reports are typically too busy with more important matters, such as making the actual repairs, to check every report. When these experienced technicians arrive on site to do the repair they come

with an assigned amount of time to perform a specified repair along with assigned spare parts and instructions to complete the specified repair. If the initial report was not accurate, the time allotted and the parts may be incorrect. A choice is then made either to perform the incorrect repair and/or to file an additional report to generate a correct work order. Either option is an expensive option in terms of time, resources and parts.

Several interim solutions have evolved simultaneously with the problem. These solutions have a fair degree of diversity, from "800" telephone numbers for customer support, to local service companies, and specialized field maintenance teams. Each of these solutions has an absolute necessity for highly technical maintenance engineering knowledge.

The present inventor have invented a process, with associated apparatus and methods, to be implemented with expert systems and computers, storing the knowledge of experienced maintenance personnel, capable of guiding a relatively inexperienced person through a complex inspection process that produces accurate work reports including time estimates and parts needed. As the system is computerized, data can be stored about past repairs and statistical studies performed outputting information useful for redesigning maintenance program tasks to be more applicable and effective, thus extending the operation life of the corresponding equipment.

## SUMMARY OF THE INVENTION

The present invention packages expert knowledge in the form of step-by-step guidelines for analyzing equipment failures, performing equipment maintenance or inspections, and generating work specifications. Access to the expert knowledge is provided by mobile computing and network technologies to enable global access to maintenance engineering knowledge and experience. By accessing the expert knowledge, users are assisted in all areas of troubleshooting that require technical expertise to evaluate the situation. The invention also provides for the capture of steps used throughout the process for training, historical tracking, forecasting, and trending analysis.

The present invention utilizes an expert system comprised of a maintenance process knowledge base and inference engine. Such a system provides equipment technicians with proven repair, calibration, and "trouble shooting" information normally obtained after years and years of experience from maintaining a single system or sub-system. In addition, the system records the decisions made by the technicians for use in future diagnostics and training sessions. Thus, the extensive knowledge base may be used as a decision support system. Transactional

maintenance data stored in the knowledge base may be analyzed to establish trends and forecasts. The results can be translated into maintenance requirements aimed at maximizing the operational availability of a system.

## BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the invention will become apparent and more readily appreciated from the following description of the preferred embodiments, taken in conjunction with the accompanying drawings of which:

FIG. 1 is a system diagram of the preferred embodiment of the present invention.

FIG. 2 is a logical diagram of the preferred embodiment of the present invention.

FIG. 3 is a data flow diagram of the preferred embodiment of the present invention.

FIG. 4 is flowchart of a maintenance wizard in accordance with the preferred embodiments of the present invention.

FIG. 5 is a data chart of a data structure used in the preferred embodiment of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made in detail to the preferred embodiment of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

The detailed description which follows is presented in terms of general procedures and symbolic representations of operations of data bits within a computer memory, associated computer processors, networks, and network devices. These procedure descriptions and representations are the means used by those skilled in the data processing art to most effectively convey the substance of their work to others skilled in the art. In the case of an object oriented system, as described herein, it is also useful to have descriptions of the objects used. A procedure is here, and generally, conceived to be a self-consistent sequence of steps or actions leading to a desired result. Thus, the term "procedure" is generally used to refer to a series of operations performed by a processor, be it a central processing unit of a computer, or a processing unit of a network device, and as such, encompasses such terms of art as "functions," "subroutines" and "programs." Objects incorporate procedures as methods.

In general, the sequence of steps in the procedures require physical manipulation of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared or otherwise manipulated. Those of ordinary skill in the art conveniently refer to these signals as "bits," "values," "elements," "symbols," "characters," "images," "terms," "numbers," "data," or the like. It should be recognized that these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities.

In the present case, the procedures are machine operations performed in conjunction with other machines and possibly human operators. Useful machines for performing the operations of the present invention include general purpose digital computers, routers, switches, and other similar devices. In general, the present invention relates to method steps, software, and associated hardware configured to process electrical or other physical signals to generate other desired physical signals.

The apparatus set forth in the present application may be specifically constructed for the required purposes or it may comprise a general purpose computer or other network device selectively activated or reconfigured by a computer program stored in the computer. The procedures presented herein are not inherently related to any particular computer or other apparatus. In particular, various general purpose machines, including PDA's, laptops, and other hand-held devices, may be used with programs in accordance with the teachings herein, or it may prove more convenient to construct more specialized apparatus to perform the required method steps. In certain circumstances, it is desirable that a piece of hardware possess certain characteristics, these characteristics are described more fully in the following text. The required structures for variety of these machines will appear in the description given below. Machines which may perform the functions of the present invention include those manufactured by such companies as Hewlett Packard, Inc., International Business Machines, Inc., CISCO, Inc., 3COM Inc., Toshiba Ltd., and Fujitsu Ltd., as well as other manufacturers of computer systems and network devices.

The application sets forth the best mode of the invention as being utilized in connection with network, including a local area network and a TCP/IP network (commonly referred to as a Intranet or Internet), however, one of ordinary skill in the art will recognize that the present invention is suitable for use on any communication network from which the appropriate data may be collected. The best network protocol and associated hardware is heavily dictated by the actual

use to which the invention is put in conjunction with the present state of the art in communication systems. Those of ordinary skill in the art recognize that other current and future communication systems will support use of the present invention, such that the invention is not limited to any particular network, but applicable to a broad range of networks.

With respect to the software described herein, one of ordinary skill in the art will recognize that there exists a variety of platforms and languages for creating software for performing the procedures outlined herein. One of ordinary skill in the art also recognizes that the choice of the exact platform and language is often dictated by the specifics of the actual system constructed, such that what may work for one type of general purpose computer may not be efficient on another type of general purpose computer. In practice, the present invention can be realized utilizing Microsoft's Visual Basic, Crystal Reports, True Grid, RoboHelp, DataWidgets, and data stored in the Backus-Naur Form. The expert system used herein can be implemented on any one of a variety of available systems. Of course, these are only examples and other development platforms can be used depending upon the exact implementation of the present invention.

FIG. 1 is a system diagram of the present invention. In general the present invention utilizes a data structure to assist in identifying the component being inspected and a related expert system to guide users through an individualized inspection operation. The database generates work orders based on the data produced during the inspection and can track inspections and repairs to provide statistical data. The setting shown in FIG. 1 is that of a system suitable for use by the U.S. Navy. Those of ordinary skill in the art will recognize the adaptability of the present invention to other fields of endeavors, including, but not limited to, any organization that has a large population of physical assets that requires periodic or planed maintenance to be performed such as: other military organizations; large equipment manufacturing; computer equipment manufacturers; and any service companies performing maintenance on residential/commercial equipment.

A variety of processing systems 10, 12, and 14 (including replications 10a and 10b of system 10) are connected via a wide area network (WAN) 16 (or the Internet). FIG. 1 shows a variety of configuration possibilities as examples only. The processing system 10 acts as a central repository for an expert system which provides interactive maintenance routines, diagnosis, repair scheduling, and statistical analysis . Commonly available expert systems may be used, the exact selection of which will vary based on how the present invention is

implemented. The use of such expert systems, including the population of data therein is largely beyond the scope of the present invention. While examples of data structures usable by such expert systems will be discussed, non-essential details regarding the use of such expert systems are omitted so as to avoid obscuring the invention.

The processing system 12 acts as a database for equipment/component data (one example of a usable data structure is given herein below), and the processing system 14 acts as a database for maintenance policy/procedures (one example of a usable data structure is given herein below). The processing systems 10, 10a, and 10b serve the expert system stored in the central repository to the maintenance personal inspecting the system under consideration. In the example shown in FIG. 1, maintenance personal access the expert system for interactive instructions on performing inspection and maintenance tasks on components of United States Naval Vessels.

The processing system 14 is connected to the WAN 16 by a local area network (LAN) 18a, while the processing system 12 is connected via a LAN 18b and the processing system 10 is connected by a LAN 18c. By way of example only, the central repository for the expert system is shown as being replicated on processing systems 10a and 10b. In general, the various data functions of the present invention are shown as being split among the processing systems 10 - 14, but those of ordinary skill in the art will recognize that this is a matter of convenience only. The function could reside on a single computer or be further distributed.

The replicated processing systems 10a and 10b are connected to local maintenance sites 22a and 22b, respectively. In the example shown in figure 1, the replicated central repository of the expert system stored on the replicated processing system 10a connects to the local maintenance site 22a, which is a shipyard, via a shipyard LAN 18d. The replicated central repository of the expert system stored on the replicated processing system 10b connects to the local maintenance site 22b, which is a ship, via a ship to shore LAN 18e utilizing a satellite 20. At the ship yard or on the ship, maintenance personal utilize a variety of computing devices 24, including a laptop 24a and a handheld PC 24b, to access the procedures of the expert system.

In general, it is preferable that the computing device 24 be portable to allow maintenance personal to carry the computing device 24 with them on each inspection. It is, however, conceivable that each component that requires maintenance be provided with a computing device. Depending on the computing power and storage capabilities of the computing devices 24, various units of the expert system are served thereto. For example, it is not inconceivable

that future portable computing devices will have the power and capacity to hold the entire system including the expert system, component data and maintenance policies. Many small handheld devices (including personal data assistants (PDAs) such at 3Com's PALM®) can store parts of the system, such as the information and routines for a type of component. Currently, wireless portable devices are entering the market. Accordingly, one option is to access the processing systems 10 through 14 when new data/objects/procedures are required. The world wide web paradigm, with the use of java applets, is useful in this context. Optional ancillary devices, such as a digital camera 26, a low frequency receiver, and a bar code scanner 30 enhance the functionality of the computing devices 24, as described herein after.

FIG. 2 is a logical diagram of the present invention. The expert system starts with a routine for identifying the component being inspected. Specifically, the computing device 24 accesses an equipment breakdown structure 32 (also known as the component breakdown structure) which maintains a hierarchal list of the various components of the system being maintained and prompts the user to select the appropriate component. This can take the form of an interactive session wherein the user is presented with a hierarchal graphical or textual representation of the ship. By selecting areas of the ship, in increasing detail, the exact component being inspected can be identified. The formation of the equipment breakdown structure 32 is performed with standard database management tools.

Instead of the interactive selection of a component, each component can be tagged, such as with a bar code or low frequency transmitter to immediately and uniquely identify the component to the computing device using the low frequency receiver 28 or the bar code scanner 30. The equipment breakdown structure 32 is linked to a relational database management system (RDBMS) 34 (such as ORACLE®) which records statistical data, such as the number of times each component is inspected.

Once the exact component is selected, a step by step instruction procedure 36 is served to the computing device 24. The instruction process interactively guides maintenance personal through an inspection routine. By using an expert system which employs a fault logic tree 38, changes in inspection routine can be interactively prompted based on the input of data based on observations of maintenance personal. The fault logic tree 38 is formed as a data structure described hereinbelow. The fault logic tree is based upon Reliability-Centered Maintenance Requirements concepts, described, for example, in MIL STD 2173(AS) Reliability-Centered

Maintenance Requirements for Naval Aircraft, Weapons Systems and Support Equipment (U.S. Naval Air Systems Command), incorporated herein by reference.

If the maintenance personal has a digital camera, he or she can be instructed to take a picture of the component to be sent with the observations. Such a digital image may provide the personal who perform any required maintenance with additional insight. If a digital camera is used, object recognition technology may be used to automatically identify the component and/or characteristics thereof.

The RDBMS 34 is also linked to the step by step instruction procedure 36 (including the fault logic tree 38) for maintaining statistical information including information on the faults experienced by each component.

The output of the step by step instruction process 38 is a work specification 40 and related reports. An example of a work specification is set forth herein below. The various reports may be linked to the RDBMS 34 for future statistical analysis.

FIG. 3 is a data flow diagram of the present invention. The computing device accesses (either through a communication link or, given sufficient computing power, internally) maintenance wizard 42 (wizard being a term of art for any help system) to present to the user interactive displays 50 to guide the user through an inspection procedure on the identified component. The maintenance wizard 42 accesses the equipment breakdown structure 32 and a business rule data base 44 to guide the inspection and produce the work specification 40.

The Data Architecture of the maintenance wizard 42 is preferably object oriented and designed with the rigor of a formal definition of a programming language grammar. This grammar consists of a set of category definitions, relationships, and rules presented in Backus-Naur form (BNF). At a high level, the architecture initially consists of five major syntactic categories; Events, Equipment Objects, Nodes, and Diagnostic Primitives. The relationships and rules provide the operational processing.

The Events are user or system selected to initiate application processing. The selected event, together with the associated Equipment Object, triggers the diagnostic processes.

Event ::= {Inquiry Event // Inspection Event // Failure Event // Diagnostic Event // Repair Option Event // Decision Event // Report Event // other to be defined later}

The Equipment Objects will have identification information, component information, and tracking/trending information from a historical perspective. Each piece of equipment will be

defined with a complete component breakdown structure in the equipment breakdown structure 32. For processing inspections or diagnostics, each component will have a relationship with one or more categories of inspections/failures modes. These categories will be equipment specific and may include classifications, such as Structural, Mechanical, Electrical, etc... where appropriate.

Note: the syntax for the language is syntactic category ::= { element // element ...} where:

the term being defined is the syntactic category;

the symbol ::= means "is defined ";

the symbol "//" is read as "or"; and

the symbols "{" "}" are used to list the set of elements.

For example: Equipment Object ::= {Equipment // Facility // ship // aircraft // others to be defined later}

An example of an Equipment Object

| Field |
|---|
| Equipment ID |
| Equipment Type |
| Manufacture |
| Location |
| Spec Data ID |
| EquipWork Breakdown Structure ID |
| Technical Manual |
| Add Change |

The equipment object would also contain the pointers to the initial node for processing according to selected events.

The nodes are the building blocks of the diagnostic process, which is implemented internally as a directed (critical path) graph. The graph consists of a minimum of two nodes.

Node ::= { Initiation Node // (Non-terminal) Evaluation Node // (Terminal)

Completion Node}

The selection of the initial node is triggered via information from the equipment object and the event. The initial node is responsible for setting up the dynamic processing and tracking mechanism. Additional nodes selection is performed based on most recent action, preset specifications, or for equipment failures, most probable cause or most severe consequences criteria. Each node will invoke navigational aids, business rules, scripts, queries, and data primitives to perform each diagnostic procedure.

A *navigational aid* assists the internal program logic in selecting the next node. This includes:

"visited" indicator to assist in backtracking and the eliminating of multiple visits and infinite loops in the path;

"success" indicator to indicate the successful path. The node is originally marked as successful. As unfruitful paths are explored and backtracked, the node will be marked unsuccessful and will not be included in the final resolution path tracking;

"severity" indicator; and

"priority" indicator.

A *Business Rule* is an equipment/site specific guideline to provide direction in the process of the associated event. Based on the equipment component and a minimum/maximum/acceptable range for the measure of failure (or inspection), the business rule will provide the direction. The direction may be in the form a repair option or an inspection guideline.

An example of a Failure Diagnostic Business Rule

| Template | Instance Sample Data |
|---|---|
| Equipment Unique ID | Pump |
| Component ID | Valve-2344 |
| Primitive Type | Failure |
| Primitive Noun/verb | Leak |
| Material | Material |
| Upper range | 10 |
| Lower range | 3 |

| | |
|---|---|
| Recommended Action | Recommended Repair Option is replacement of component |
| Severity | Critical |

A *Script* is a grammar structure that provides a representation of a stereotyped situation by building a coherent interpretation from a collection of observations and data elements. The script has an entry condition that must be met in order to trigger the processing of the script. The data from the equipment object, the triggering Event, and nodal primitive is associated with each slot in the script to develop a meaningful scenario. For any null valued data element in the object, event, or primitive, a default data element will be associated and used within the script. The output from scripts may be the generation of instructions, documentation, work specifications, or other system defined products. A script may also be used to build the parameters for invoking an external program or trigger an internal or database process.

A *query* is a user interface mechanism to collect observations and assist in navigating the alternatives in the critical path. The query mechanism will be used to insert data into the required fields of the data primitive.

A *data primitive* is an atomic level data structure. Primitive templates may be used for potential failure modes or inspection criteria. Accordingly these primitives form the fault logic tree 38. They are developed and loaded at the initial creation of the application. These templates provide the definition of data elements to be collected during the processing of the application. Additional primitive templates may be added dynamically through a drag/drop or user key entry to define the meta-data for the template. During this process the user will define the number of data elements (n-tuple) and the definition, data type, and default values for each field of the tuple. These primitives will be used to either guide the step-by-step diagnostics or store results of inspections.

Data Primitives = {Failure Description Primitives // Inspection Primitives // ...}

Failure Description Primitive = eight-tuple consisting of (verb, quantity, measurement type, material, severity, priority, comment)

An example of a Failure Description Primitive

| Template | Instance Sample Data |
|---|---|
| Action noun/verb | Leak |
| Quantity | 4 |
| Measure | Drops/minute |
| Material | Oil |
| Severity | |
| Priority | |
| Comment | |

The severity and priority fields allow the system to notify maintenance personal how serious the situation is to enable efficient work planning.

Inspection Primitive = eight-tuple consisting of (verb, measure, measure tolerance, acceptable lower bound, acceptable upper bound, pass/fail, recommended action)

An example of an Inspection Primitive

| Template | Instance Sample Data |
|---|---|
| Action noun/verb | Temperature |
| Measure | degrees |
| Measure tolerance | 2 degrees |
| Lower Bound | -30 |
| Upper Bound | 240 |
| Pass/Fail Criteria | Pass if within bounds |
| Recommended Action | If within 10 degrees of either bound, schedule recheck at next inspection |

Most of the objects and templates will be populated during construction of the system. Other objects are populated during the interactive inspection procedure. Expert knowledge from experience maintenance personal will be required to construct many of the objects for the expert system. Specifically the Equipment Objects, Failure Diagnostic Business Rules, Failure Description Primitives, and Inspection Primitives require expert input to construct. It should be noted that these may be provided with new equipment by the manufactures of the

equipment. This would simplify the creation procedure immensely.

FIG. 4 is flowchart of the maintenance wizard 42 in accordance with the preferred embodiments of the present invention. The procedure starts in step S1 with the login of the user. Next in steps S2 through S3 the component is selected. In step S1 the appropriate equipment breakdown structure 32 is accessed (either through user choice or automatically as being pre-programmed or using a bar code or the like). Thereafter in step S3, the top level component is selected using the selected equipment breakdown structure 32. Finally, in step S4 the actual component (sub-component) being inspected is selected from the equipment breakdown structure 32. This process may require a plurality of iteration to dig down to the correct component, Fig. 4 only shows three levels by way of example. As noted above, this step can be automated using a variety of mechanisms, such as bar coding and low frequency transmitters.

Next, in step S5 the business rules database 44 is accessed and failure modes are identified. In step S6, a fault tree analysis is performed by accessing the fault tree tables 46 (forming the fault tree logic 38) and an equipment history database 48. A knowledge and inference engine (not shown) can be used to identify the most recent, sever or most common failures to aid in navigating the fault-tree paths. Finally, in step S7 a work specification 40 is generated. Other reports, such as an estimate report 40a can also be generated.

FIG. 5 is a data chart of a data structure which may be used in the present invention. This is provided as an example for those of ordinary skill in the art. Many possible variations would produce a usable system. The following chart describes the elements in the data chart.

| Entity Name | Attribute Name | Description |
|---|---|---|
| ComponentType | ComponentCode | Code of the component type. |
| ComponentType | DiscID | Code of discrepancy type. |
| ComponentType | ComponentDesc | Component description. |
| Discrepancy | DiscID | Code of discrepancy type. |
| Discrepancy | DiscDescription | Detailed Description of the discrepancy. |
| EquipmentConfiguration | CfSysKey | System generated unique identifier for all configuration item records in the Equipment Configuration table. |
| EquipmentConfiguration | ESWBSID | Equipment system work breakdown structure identifier. A numeric numbering system used to identify a components relation to its hierarchical sub-system or system. |
| EquipmentConfiguration | ShipUIC | "Highest level node system identifier. For this example, uniquely identifies each component's parent node." |
| EquipmentConfiguration | Workcenter | Code identifier for the work center that services the equipment component. |
| EquipmentConfiguration | APL | Allowance Part List. Lookup code for a parts list associated with the component. |
| Equipment Configuration | Noun Name | Abbreviated description of the equipment component. |
| Equipment Configuration | EquipID | Unique identifier for the equipment component. |
| Equipment Configuration | EIC | Equipment Identification Code. Smart coded identifier for equipment. Optional |
| Equipment Configuration | Location | Identifier of the location occupied by the equipment component. |
| Equipment Configuration | SupNomen | Abbreviated component description containing basic manufacturer specifications. |
| Equipment Configuration | RIN | Record Identification Number |
| Equipment Configuration | TechManual | Publication code of the technical manual for the corresponding component. |
| Equipment Configuration | AddChange | Record of any additions or changes made to the equipment configuration item. |
| Equipment Configuration | ESWBSCode | Code of equipment's system or subsystem. |
| Estimate | Repair | Abbreviated description of the repair. |
| Estimate | TradeMHr | Trade and associated Man-hr rate. |
| Estimate | Material | Rate of material associated with the repair. |
| ESWBS | ESWBSID | Equipment system work breakdown structure identifier. A numeric numbering system used to identify a components relation to its hierarchical sub-system or system. |
| ESWBS | Description | Abbreviated description of the equipment system work breakdown structure. |

| | | |
|---|---|---|
| EventHistory | CfSysKey | System generated unique identifier for all configuration item records in the Equipment Configuration table. |
| Grid | QuestionCode | Related question code generated by wizard. |
| Grid | ColumnName | Name of grid column heading. |
| Grid | ColumnOrder | Order of column in the grid. |
| Grid | SubQuestCode | Related sub Question Code |
| Grid | GridCode | Uniquely identifies records in the grid table. |
| Question | QuestionCode | Question code generated by wizard. |
| Question | DiscrepancyCode | Discrepancy code of question. |
| Question | ComponentCode | Component code of question. |
| Question | QuestionText | Text of question. |
| Question | QuestionType | Numeric lookup code identifying the type of question. |
| Question | QuestionOrder | Order number that the question appears on the form. |
| Question | InstuctionText | Additional instructional text. (for completing free hand text input) |
| Question | QuestionLabelDescriptor | Question label description to store with answer. |
| Selection | SelectionCD | Selection Code |
| Selection | QuestionCode | Question code generated by wizard. |
| Selection | SubQuestCode | Sub Question Code |
| Selection | Selection | Selection text. |
| Selection | flagSubQuest | Sub question exists flag (y or n) |
| SpecData | SpecDataID | Unique identifier of a system generated work specification. |
| SpecData | CfSysKey | System generated unique identifier for all configuration item records in the Equipment Configuration table. |
| SpecData | Problem | Text description of problem potential problem associated with an equipment component. |
| SpecData | Repair | Recommended repair associated with an equipment problem. |
| SpecData | Title | Title of the recommended repair. |
| SpecData | Configuration | "Text description data based on equipment descriptive data. Includes a concatenation of descriptive attributes (e.g. work center, serial number, location, ESWBS)." |
| SpecData | Identification | "Text description based on manufacturers specifications such as: manufacturer, capacity, APL, etc." |
| SpecData | ReferenceInformation | Text field of information that references supporting technical documents such as MIL Standards. |
| SpecData | SOW | State of work needed to be accomplished in order to restore the basic function of the equipment. |
| SpecData | BOM | Bill of material. |
| SpecData | TestInpsect | Itemized list of steps required to test the state of the equipment based on the identified problem. |
| SpecData | Estimate | Concatenation of Labor and Material rates. |
| SpecData | TradeEsitmate | List of industrial trades and estimate hours required to accomplish the repair if available. |

| | | |
|---|---|---|
| Spinner | SpinnerCode | Spinner code. Code associated with a question and sub-question. Provides parametric values for testing and evaluation. |
| Spinner | SubQuestCode | Sub Question Code |
| Spinner | QuestionCode | Question code generated by wizard. |
| Spinner | MinValue | Minimum value of spinner selection. |
| Spinner | MaxValue | Maximum value of spinner selection. |
| Spinner | Increment | Increment of spinner selection. |
| Spinner | Measure | Spinner measure. |
| SubQuestion | SubQuestCode | Sub Question Code |
| SubQuestion | SelectCode | Selection code. |
| SubQuestion | SubQuestText | Sub question text. |
| SubQuestion | SubQuestType | Sub question type. |
| SubQuestion | SubQuestOrder | Sub question order. |
| SubQuestion | SubQuestLabel | Description of sub-question to store with answer. |
| SubQuestion | SubQuestInstruction | Instruction text for a subquestion. |
| WorkBreakdownStructure | ESWBSCode | Code of equipment's system or subsystem. |
| WorkBreakdownStructure | ESWBS Description | Description of equipment system work breakdown structure. |

The system utilizes the failure diagnostic business rules, failure description primitives, and inspection primitives to output work specifications 40. The following is an example of such a specification:

Preliminary Specification

SHIP: USS INCHON (MCS-112) ITEM NO. 521-11-001

COAR: EB14-1126 16-025 PCN:

CMP: NONE

SURVEYOR:

1. SCOPE:

1.1 Title: Fire Pump Mechanical Seal; replace

1.2 Location of work:

1.2.1 Auxiliary Machinery Room No. 2 (5-260-0-E)

1.3 Identification:

1.3.1. Quantity (One EA), Pump: No. 1 Fire Pump, Mechanical Seal, Worthington Pump Corp., Mfg. Dwg. By -173728, Mfg. Id. 10LRN-12, APL: 016032515

2. REFERENCES:

Standard Items

S6225-KM-MMA-010, Fire Pump Model No. 10LRN-12

MIL-STD-1310, Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility and Safety

52421-3-700B, Fire Pump and Motor Functional Test

3. REQUIREMENTS:

3.1 Remove and dispose of fluids to accomplish requirements of this work Item.

3.2 Inspect each foundation and bedplate for structural deterioration, cracks, and areas of distortion.

3.2.1 Remove dirt, oil, and grease. Remove rust, scale, and loose paint to bare metal. Existing well adhered paint may be left intact.

3.2.1.1 Submit four legible copies of a report listing results of the requirements of foundation and bedplate inspection for each pump to the SUPERVISOR.

(I) "VERIFY NEW PARTS"

3.3 Install new mechanical seal, using 2.b for guidance.

3.3.1 Remove existing, fit, and install new the following parts:

| TOTAL QUANITY PART REQUIRED | NAME OF PART | PIECE NO. | PIECE NO. | REF. DRAWING NO. | FIGURE NO. |
|---|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| One EA 807188-21 Mechanical | Seal | 53 | 2.b | 7-2 |

3.4 Install equipment listed in 1.3, using 2.b for guidance.

3.4.1 Align each pump and motor to bedplate.

3.4.1.1 Install new hold-down bolts conforming to MIL-S_1222, III, Grade 5 and self-locking nuts conforming to MIL-N-25027, steel. Fasteners shall have protective coating per MIL-C-81751, Type I, Class 4; MIL-C-87115, Class 3; MIL-C83488, Type II, Class 3, or A STM B-633, Type II, Class 133.

3.5 Accomplish the requirements of 009-58 of 2.a for the equipment listed in 1.3, using 2.b for guidance.

( I ) "VERIFY ALIGNMENT"

3.5.1 Inspect alignment of each coupling prior to bolting coupling.

( I ) "SHAFT ROTATION"

3.5.1.1 Manually rotate each shaft. Rubbing or binding of rotating assembly is not allowed.

( I ) ( G ) "OPERATIONAL TEST"

3.6 Accomplish the requirements of 2.d. Boundaries for test shall be as follows: No. One Auxiliary Seawater Pump, Motor.

3.6.1. Submit four legible copies of a report listing results of the requirements of 3.6 to the SUPERVISOR.

3.7 Accomplish the requirements of 009-32 of 2.a for new and disturbed surfaces.

4. NOTES:

4.1 None.

5. GOVERNMENT FURNISHED MATERIAL (GFM):

5.1 None.

# WORK CANDIDATE

| | | | | |
|---|---|---|---|---|
| ITEM NUMBER | MASTER JOB CATALOG # | 2L | QA | SHIP<br>USS INCHON (MCS-12) |
| ESWBS<br>52121 | EIC<br>T801360 | APL<br>018880296 | RIN<br>A1725 | |
| EQUIPMENT NAME<br>FIRE PUMP | IDENT/SERIAL<br>NR.1 | LOCATION<br>5-129-0-E | WORK CENTER<br>EM01 | JSN<br>A001 |
| EQUIPMENT STATUS | PROBLEM STATUS | CATEGORY | EOC | |
| | DEFER DATE<br>9149 | DEADLINE DATE | | |
| TYPE AVAIL<br>1 | WHEN DISCOVERED<br>9149 | STATUS<br>1 | CAUSE<br>7 | DEFERRAL REASON<br>6 |
| MAN HOURS EXPENDED<br>0001 | MAN HRS REMAINING<br>0001 | S/F MANHOURS | PRIORITY<br>1 | |
| SAFETY HAZARD | COMPLETED ACTION TAKEN | | | |
| DISCREPANCY DESCRIPTION<br>FIRE PUMP MECHANICAL SEAL IS LEAKING APPROXIMATELY 50 DROPS PER MINUTE. XXX REPLACE MECHANICAL SEAL. | | | | |
| CSMP SUMMARY<br>MECHANICAL SEAL LEAKING | TEST # | | | |
| ROOT CAUSE/AMPLIFICATION | STEP # | | | |
| SYSTEM LEVEL IMPACT | | | | |

| NOMENCLATURE | QTY | COG | NSN | DOC NR | STATUS |
|---|---|---|---|---|---|
| | | | | | |

TECHNICIAN MARK APPROPRIATE BLOCKS EM01A001
2-KILO IS:

___ V. VALID ___ C. FOUND COMPLETE

___ T. COMPLETED BY TECH/SHIPS FORCE ___ W. REWRITTEN

___ X. CANCEL ___ N. NOT VALIDATED

| | | | |
|---|---|---|---|
| FIRST CONTACT<br>BURLAND | RATE<br>CIV | SECOND CONTACT<br>MARTINCHICK | PHONE |
| BLUEPRINTS, TECHMANUALS, PLANS, ETC. | | | ON BOARD ? |

| | | | | | |
|---|---|---|---|---|---|
| ASSESSOR/ACT/TECH ID # | TECH CODE<br>SNAP05 | TD | LOGISTICIAN | SHIPS REP | PE |

In accordance with the foregoing model, such a work specification is automatically prepared based upon an inspection routine. Further, using such a document, the system can

easily be adapted to produce time estimates and be integrated into a work scheduling system. As noted above the system can interface with a statistical RDBMS for the creation of statistical forecasting, and/or trending reports, such as breakdown/repair frequency reports. Using these reports, the users and suppliers of the components can redesign maintenance program tasks when certain failure modes are noted.

Although a preferred embodiment of the present invention has been shown and described, it would be appreciated by those skilled in the art that changes may be made in the embodiment without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents. For example, if implemented as a web based application, the system could would also provide the capability to track and trend customer problems. The suppliers of component would benefit by tracking the frequency of problems and focusing customer support and future enhancements appropriately. The software could then assist in the ordering replacement parts using the stored component breakdown structure. This capability would provide a commercially competitive advantage, save research time to determine for the specific part for that make/model, and provide better support to the customer's maintenance efforts.

## CLAIMS

What is claimed is:

1. A maintenance assistance system comprising:

a main processing system storing and serving a component breakdown structure for at least one system and an inspection wizard that utilizes a data structure for guiding an inspector through an inspection process; and

a remote processing system that accesses the main processing system to allow an on-site inspector access to at least a portion of the component breakdown structure and the data structure of the inspection wizard.

2. The maintenance assistance system, as set forth in claim 1, further comprising:

a network connecting the main processing system with the remote processing system.

3. The maintenance assistance system, as set forth in claim 2, wherein the network has a wireless portion.

4. The maintenance assistance system, as set forth in claim 2, wherein the network utilizes the Internet.

5. The maintenance assistance system, as set forth in claim 1, wherein the remote processing system is a PDA class computing device.

6. The maintenance assistance system, as set forth in claim 1, wherein the remote processing system is a handheld class computing device.

7. The maintenance assistance system, as set forth in claim 1, wherein the remote processing system is a laptop class computing device.

8. The maintenance assistance system, as set forth in claim 1, wherein the component breakdown structure is a hierarchal data structure.

9. The maintenance assistance system, as set forth in claim 1, further comprising:

a bar code reader for reading bar codes on components; and

wherein the component breakdown structure is a table relating the bar codes on the components to an identification of the component.

10. The maintenance assistance system, as set forth in claim 1, further comprising:

a receiver for receiving an identification signal from transmitters related to the components; and

wherein the component breakdown structure is a table relating the identification signals from the components to an identification of the component.

11. The maintenance assistance system, as set forth in claim 1, wherein the inspection wizard comprises an expert system.

12. The maintenance assistance system, as set forth in claim 11, wherein the expert system relates questions to be asked to each component and, if required, to answers of previous questions.

13. The maintenance assistance system, as set forth in claim 11, wherein the expert system is accessed using the identification of the component being inspected from the component breakdown structure.

14. The maintenance assistance system, as set forth in claim 1, wherein the main processing system further stores an output routine for generating work specification for a component being inspected using the inspection wizard.

15. The maintenance assistance system, as set forth in claim 1, wherein the main processing system further stores statistical routines for analyzing the inspections and producing statistical reports on past inspection.

16. The maintenance assistance system, as set forth in claim 15, wherein the statistical procedures produce trending or forecasting reports.

17. The maintenance assistance system, as set forth in claim 1, further comprising an imaging system in communication with the remote processing system which transmits an image of the component being inspected to the main system.

18. The maintenance assistance system, as set forth in claim 14, further comprising an imaging system in communication with the remote processing system which transmits an image of the component being inspected to the main system and wherein the reporting system includes the image with the work specification.

19. A maintenance assistance system comprising:

main processing means for storing and serving a component breakdown structure for at least one system and an inspection wizard that guides an inspector through an inspection process; and

remote processing means for accessing the main processing system to allow an on-site inspector access to at least a portion of the component breakdown structure and the inspection wizard.

20. A computer readable medium encoded with a mobile maintenance program comprising procedures and/or objects for performing the actions:

accessing a component breakdown structure to identify a component of a system being inspected;

accessing expert knowledge to guide an on-site inspector through an inspection process of the component;

recording the inspector's observations; and

producing a work specification, when required, describing any required maintenance to be performed on the component.

21. A computer readable medium, as set forth in claim 20, wherein the component breakdown structure is stored in a hierarchal format.

22. A computer readable medium, as set forth in claim 20, further comprising procedures

or objects for forming a communication link between a main processing system storing data required for the inspection and a remote processing system used by the on-site inspector.

23. A computer readable medium, as set forth in claim 20, wherein the component breakdown structure is stored in a hierarchal format.

24. A computer readable medium, as set forth in claim 20, further comprising an expert system for performing the action of accessing expert knowledge.

25. A computer readable medium, as set forth in claim 20, wherein the component breakdown structure is stored in a table format relating an identifier on the component to an identifier of the component.

26. A computer readable medium, as set forth in claim 25, wherein the identifier on the component is one of a bar code, a signal transmitter, and a visual indicator.

27. A computer implemented method for conducting an inspection of a component comprising:

using a portable computing device to access a component breakdown structure to identify a component of a system being inspected;

using the portable computing device to access expert knowledge to guide an on-site inspector through an inspection process of the component;

recording the inspector's observations; and

producing a report regarding the inspected component.

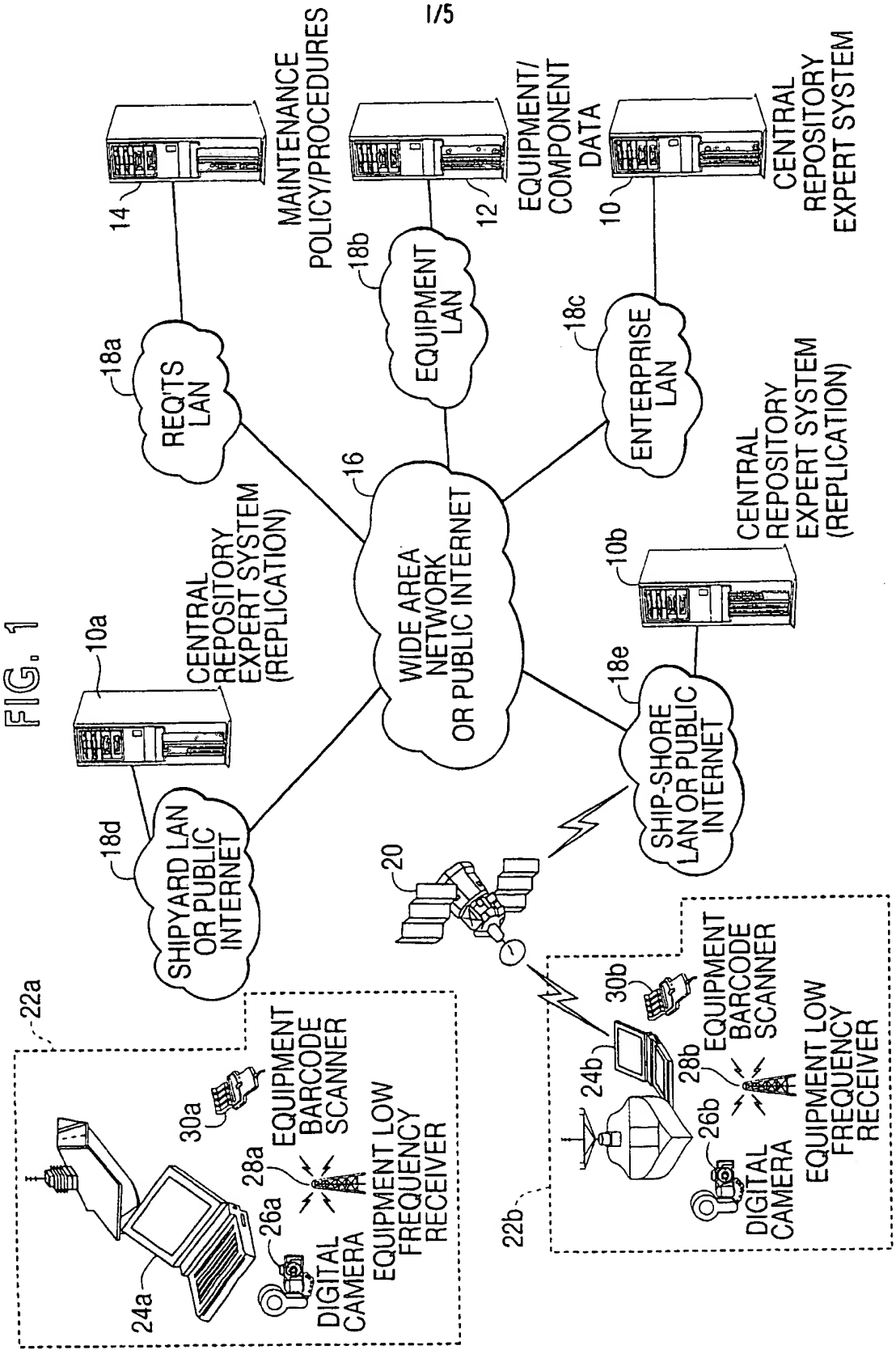
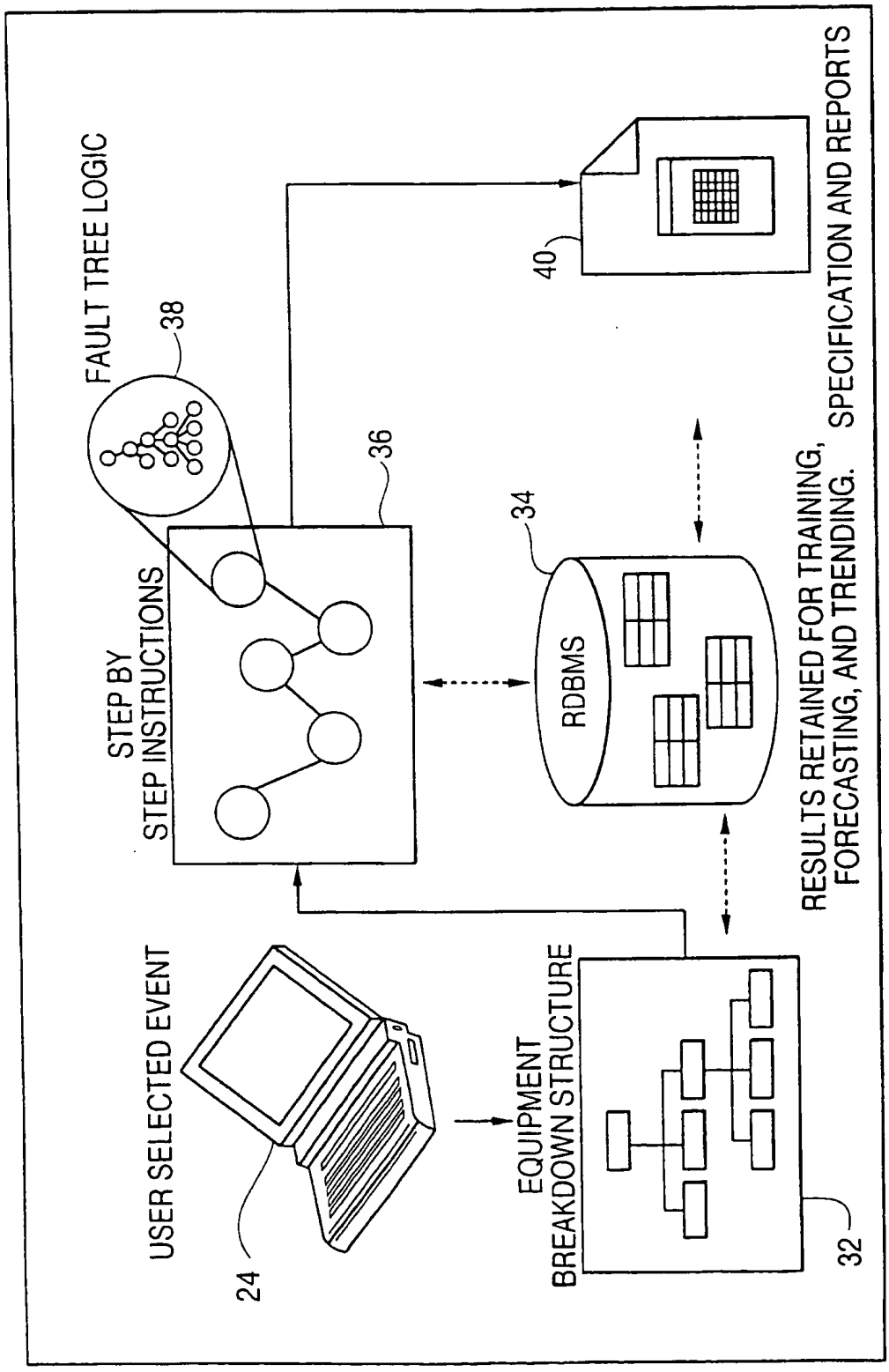



FIG. 1

FIG. 2



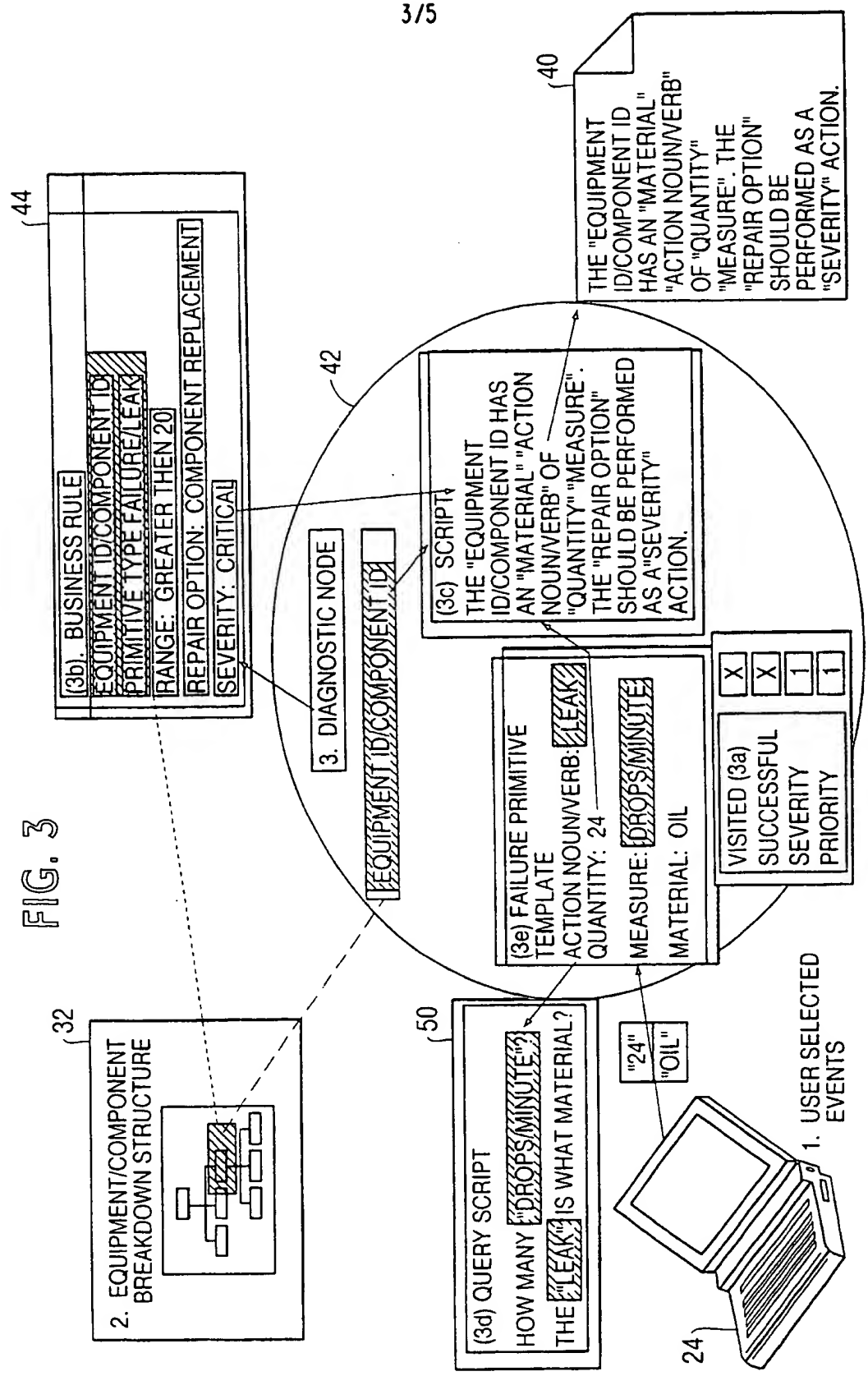



FIG. 3

FIG. 4

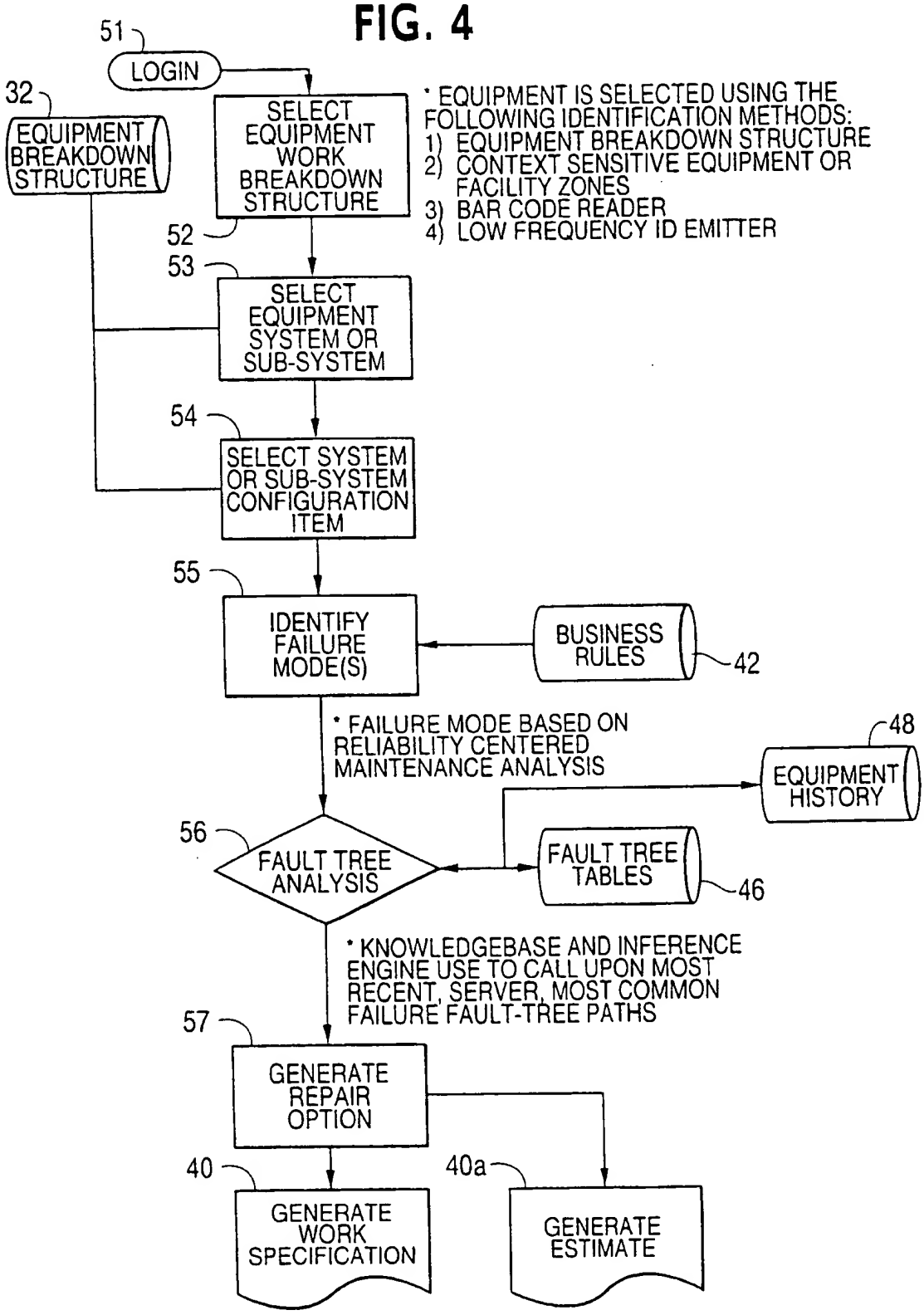
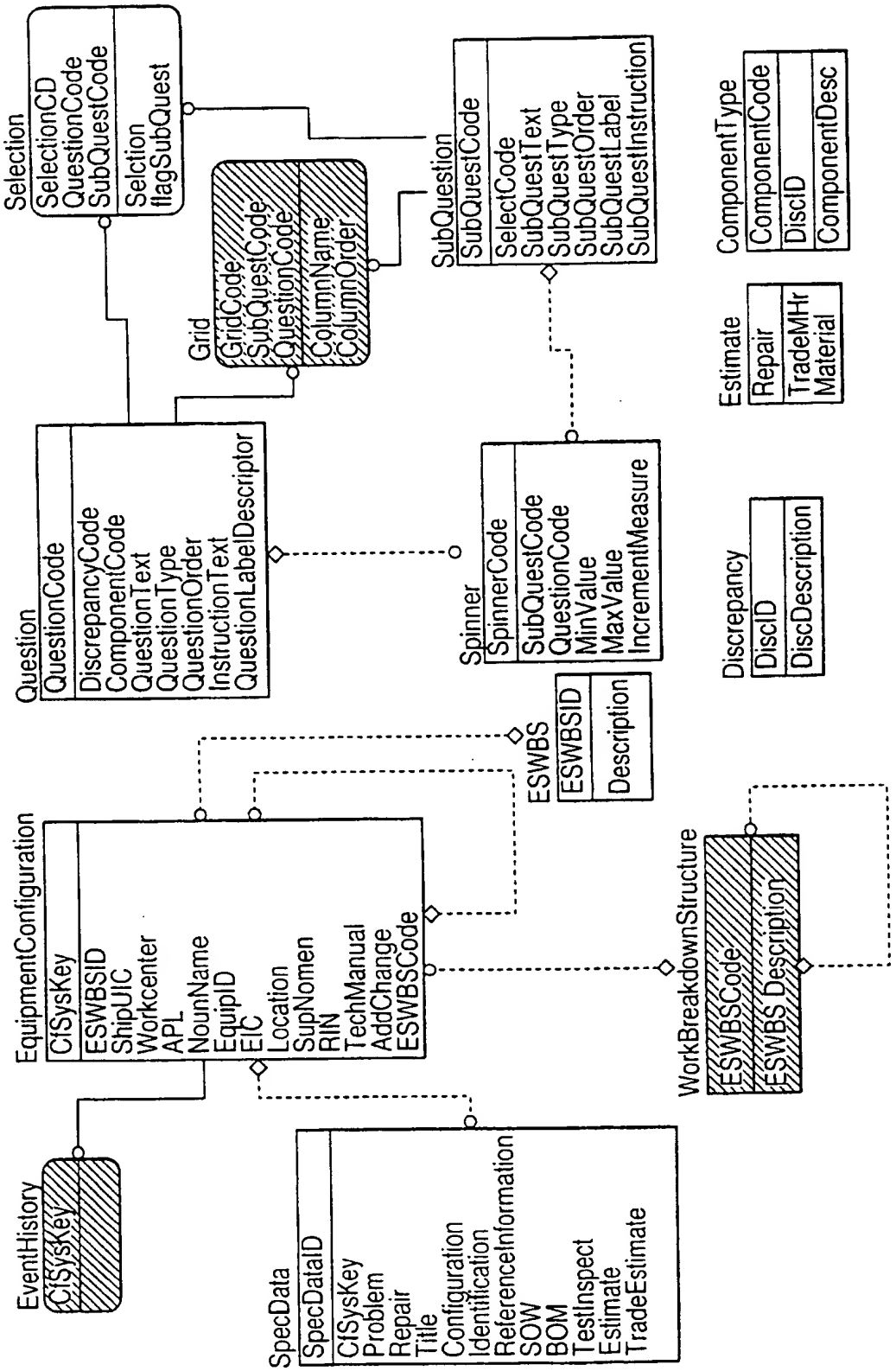


FIG. 5



# INTERNATIONAL SEARCH REPORT

Interr nal Application No
PCT/US 00/19662

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F11/25 G06F11/273 G01R31/319

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06F G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

'A' document defining the general state of the art which is not considered to be of particular relevance

'E' earlier document but published on or after the international filing date

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'&' document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 11 January 2001 | 18/01/2001 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Sarasua, L. |

Form PCT/ISA/210 (second sheet) (July 1992)

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